Operative Outcomes of Adult-to-Adult Right Lobe Live Donor Liver Transplantation

A Comparative Study With Cadaveric Whole-Graft Liver Transplantation in a Single Center

*Chi Leung Liu, MS, MD, FRCS (Edin), FACS,**
*Sheung Tat Fan, MS, MD, PhD, DSc, FRCS (Glasg & Edin), FACS,**
Chung Mau Lo, MS, FRACS, FRCS (Edin), FACS, William Ignace Wei, MS, FRCS (Edin), FACS,**
See Ching Chan, BDS, MBBS, MS, FRACDS, FRCS (Edin), Boon Hun Yong, MBBS, FRCP (Edin), FANZCA,†*
*and John Wong, PhD, FRACS, FRCS (Edin), FACS**

Objective: To evaluate and compare the operative and survival outcomes of patients who underwent right lobe live donor liver transplantation (RLDLT) and cadaveric whole-graft liver transplant (CWLT) recipients in a single institution.

Summary Background Data: Current data suggest that RLDLT has an inferior graft survival outcome when compared with CWLT.

Patients and Methods: A prospective study was performed on 180 consecutive adult patients who underwent primary liver transplantation from January 2000 to February 2004. The operative and survival outcomes of RLDLT (n = 124) were compared with those of CWLT (n = 56).

Results: Fifty-five (44%) and 16 (29%) patients were on high-urgency list in the RLDLT group and the CWLT group, respectively ($P = 0.045$). The preoperative Model for End-Stage Liver Disease scores were comparable in both groups. The waiting time for liver transplantation was significantly shorter in the RLDLT group. The graft weight to estimated standard liver weight ratio was significantly lower in the RLDLT group. The postoperative hospital stay and hospital mortality were comparable in the RLDLT group (1.6%) and the CWLT group (5.4%). Thirty-one (25%) patients in the RLDLT group and 3 (5%) patients in the CWLT group developed biliary stricture on follow-up ($P = 0.002$). At a median follow-up of 27 months, the actuarial graft and patient survival rates were 88% and 90%, respectively, in the RLDLT group, and both were 84% in the CWLT group.

Conclusion: RLDLT results in favorable operative outcomes comparable with those of CWLT. However, there is a significantly higher incidence of biliary stricture associated with RLDLT.

(*Ann Surg* 2006;243: 404–410)

Adult-to-adult live donor liver transplantation using right lobe grafts (RLDLT) has emerged successfully to partially relieve the refractory shortage of cadaveric grafts because of the increasing demands of patients with end-stage liver diseases.[1] Previous published data reported the technical feasibility of the procedure and the short-term graft and patient survival outcomes.[2–6] Right lobe liver grafts are, in general, considered marginal grafts and are not recommended for patients with poor preoperative status, including patients with fulminant hepatic failure and acute decompensation of chronic liver disease.[7–9] However, the mortality rate of these patients on liver transplant waiting list remains high, especially in Eastern societies where the availability of cadaveric liver grafts is scarce. RLDLT renders a realistic hope to the patients and their relatives. On the other hand, despite selecting recipients with better health status before liver transplantation, RLDLT did not result in better patient survival outcome compared with cadaveric whole-graft liver transplantation (CWLT).[7] Recent studies also suggested inferior graft survival outcomes after RLDLT compared with those of CWLT recipients.[8,9] However, a detailed comparison of the operative outcomes between these 2 groups of patients in a single center has not been reported so far. Our initial experience has demonstrated the feasibility of RLDLT in patients with acute liver failure, resulting in a satisfactory short-term survival outcome.[10] In this study, a prospective evaluation was performed on 180 consecutive adult patients who underwent primary liver transplantation from January 2000 to February 2004, comparing the operative outcomes of RLDLT with those of CWLT.

From the Centre for the Study of Liver Disease and Departments of *Surgery and †Anesthesiology, University of Hong Kong, Pokfulam, Hong Kong, China.

Supported by Sun C.Y. Research Foundation for Hepatobiliary and Pancreatic Surgery of the University of Hong Kong.

Reprints: Sheung Tat Fan, MD, PhD, Department of Surgery, University of Hong Kong, Queen Mary Hospital, 102 Pokfulam Road, Hong Kong, China. E-mail: hrmsfst@hkucc.hku.hk.

ISSN: 0003-4932/06/24303-0404
DOI: 10.1097/01.sla.0000201544.36473.a2

PATIENTS AND METHODS

From January 2000 to February 2004, 180 consecutive adult patients with end-stage liver diseases underwent primary liver transplantation at the University of Hong Kong Medical Centre, Queen Mary Hospital. These included 124 patients who underwent RLDLT (RLDLT group) and 56 patients who underwent cadaveric whole-graft liver transplantation (CWLT group). Patients who were in the pediatric age group (<18 years) underwent retransplantation, split-liver transplantation, and live donor liver transplantation using left lobe liver grafts were excluded from the present analysis. All patients underwent pretransplant evaluations and were accepted on a single liver transplantation waiting list.

Once the diagnosis of end-stage liver disease and the need for liver transplant were established, detailed counseling was provided to the patients and their relatives. Information provided included the prognosis with and without a timely liver transplantation, the chance of obtaining a timely cadaveric liver graft,[11] outcomes of cadaveric liver transplantation and LDLT, option of LDLT, and the risks involved in the donor operation. The potential donor was identified by himself or herself, and not by the medical staff to ensure true voluntarism. Complete psychologic assessment was then performed by a clinical psychologist, and the voluntary intention of the potential donor for liver donation without coercion was confirmed.

The second stage of donor evaluation consisted of a medical assessment of the donor, including blood group, blood biochemistry, and hepatitis serology. Anatomic assessment of the potential liver graft was performed with computed tomography (CT) and conventional hepatic angiography in the early part of the series. Conventional angiography has been replaced by CT angiography since 2002. The volumetric measurement of both the right and left lobes of the liver of the potential donor was performed. The estimated right lobe liver graft volume should be larger than 40% of the recipient standard liver volume.[12,13] To ensure safety of the liver donor, the estimated donor liver remnant by CT should be greater than 30% of the total liver volume with minimal fatty change.[14] Routine liver biopsy of the donors was not performed, unless there was a clinical suspicion of fatty change of the liver on blood biochemistry or CT scan. Evaluation of the donors' biliary anatomy was not performed preoperatively and was relied on intraoperative cholangiography using fluoroscopy, as we have reported previously.[15]

The donor and recipient operations of RLDLT were performed as described previously.[16] In all cases except for 1 donor, the middle hepatic vein was included in the right lobe liver grafts. Hepatic venoplasty was performed to join the middle hepatic and right hepatic veins of the graft to form a triangular opening for a single anastomosis to the recipient's inferior vena cava without the need of any interposition graft.[17] Venovenous bypass and temporary portocaval bypass were not used in any of the patients.[18] Arterial anastomosis was performed using microvascular technique under an operating microscope. Biliary reconstruction has been performed primarily with a duct-to-duct anastomosis whenever possible without biliary stent or drainage since March 2001.[15] Cell-saver was used during the recipient operation except in patients who had malignancy. Standard antibiotic therapy with gram-negative and gram-positive coverage was administered for 5 postoperative days. Lamivudine, 100 mg daily, was given orally for patients with hepatitis B viral infection before transplantation and continued indefinitely afterward. Hepatitis B immunoglobulin was not used in any of the patients.[19] Immunosuppression induction therapy was provided with 2 doses of steroid (intraoperatively and on postoperative day 1) and 2 doses of interleukin-2 receptor antagonist (intraoperatively and on postoperative day 4).[20] The postoperative immunosuppression was based on a low dose FK506 (serum trough level of 5–10 ng/mL) and mycophenolate mofetil. Maintenance steroid was not given. All the recipients also received oral fluconazole 200 mg daily after the operation for 3 months.

Patients who did not opt for RLDLT or those who had no suitable donors available were maintained on the liver transplant waiting list for cadaveric liver grafts. Patients with acute liver failure or acute decompensation of chronic liver diseases, who were intensive care unit (ICU) bound and on life support, were considered having the highest priority to receive cadaveric liver grafts. Allocations of cadaveric grafts for the remaining patients with chronic liver diseases were based on the Model for End-stage Liver Diseases (MELD) scores[21] and identical blood group. Surgical procedures of CWLT were performed according to what have previously been described.[22] Direct duct-to-duct biliary reconstruction was performed for all patients undergoing CWLT without T-tube or internal biliary drainage during the study period. Postoperative management including the immunosuppression regimen was identical to that of the RLDLT group.

All clinical data were collected prospectively and managed by 2 research assistants. The clinical details, operative outcomes, and survival outcomes of the 124 RLDLT recipients were compared with those of the 56 patients who underwent CWLT during the same study period. Continuous variables were expressed as median (range) and compared using the Mann-Whitney U test. Categorical variables were compared using the χ^2 test or Fisher exact test where appropriate. Graft and patients survival analysis after liver transplantation was estimated by the Kaplan-Meier survival method. Statistical comparison of survival distributions was analyzed by log-rank tests. Statistical significance was defined as $P < 0.05$. All statistical analyses were performed using SPSS for Windows 11.0 computer software (SPSS Inc., Chicago, IL).

RESULTS

Among the 124 patients who underwent RLDLT during the study period, there were 97 men and 27 women with a median age of 47.5 years (range, 18–68 years). Details of the clinical parameters of patients in the RLDLT and CWLT groups are listed in Table 1. Indications for liver transplantation in the RLDLT group were end-stage liver disease resulting from liver cirrhosis (n = 69), fulminant hepatic failure (n = 9), and acute-on-chronic hepatic failure (n = 46). Details of the indications for liver transplantation in both groups of patients are outlined in Table 2. Inclusion of

TABLE 1. Preoperative Clinical Parameters of 124 Patients Who Underwent Right Lobe Live Donor Liver Transplantation (RLDLT) and Those of 56 Patients Who Underwent Cadaveric Whole-Graft Liver Transplantation (CWLT)

Parameter	RLDLT Group	CWLT Group	*P*
No. of patients	124	56	—
Male:female	97:27	44:12	0.958
Age (yr) [median (range)]	47.5 (18–68)	48 (27–66)	0.865
Chronic hepatitis B infection	104 (83.9%)	46 (82.1%)	0.773
Hepatocellular carcinoma	36 (29%)	11 (19.6%)	0.184
MELD scores [median (range)]	21 (7–46)	19 (6–49)	0.396
Fulminant hepatic failure	9 (7.3%)	0	0.059
Acute-on-chronic hepatic failure	46 (37.1%)	16 (28.6%)	0.265
Patients in intensive care unit	58 (47%)	17 (30%)	0.039*
Patients on life support	23 (18.5%)	5 (8.9%)	0.099
Serum total bilirubin (μmol/L) [median (range)]	155 (13–940)	79 (8–984)	0.191
Serum AST (U/L) [median (range)]	85.5 (26–10,000)	62.5 (11–922)	0.003*
Blood ammonia (μmol/L) [median (range)]	75 (4–275)	61 (18–713)	0.312
Prothrombin time (s) [median (range)]	23.1 (12.1–89.5)	19.1 (11.1–58.5)	0.110
Waiting time on list (days) [median (range)]	14 (1–1406)	237 (1–1359)	<0.0001*

*$P < 0.05$.
AST indicates aspartate aminotransferase; MELD, model for end-stage liver disease.

patients with hepatocellular carcinoma in the transplant waiting list generally followed the Milan criteria,[23] and 36 (29%) patients in the RLDLT group and 11 (20%) patients in the CWLT group had concomitant hepatocellular carcinoma. Fifty-five (44%) patients in the RLDLT group and 16 (29%) patients in the CWLT group were on high-urgency list for liver transplantation ($P = 0.045$). Twenty-three (19%) of them were on life support before operation in the RLDLT group. The corresponding figure in the CWLT group was 5 (9%). The preoperative liver function appeared to be worse in the RLDLT group with a higher serum total bilirubin level and longer prothrombin time, although the differences did not reach statistical significance. The preoperative MELD scores in patients with chronic liver diseases were comparable in both groups (median, 21 versus 19, $P = 0.396$). The waiting time for liver transplantation was significantly shorter in the RLDLT group (median, 13.5 days versus 237 days, $P < 0.001$).

TABLE 2. Indications for Liver Transplant for the RLDLT Group and the CWLT Group

Indication	RLDLT Group	CWLT Group
Cirrhosis of liver		
Chronic hepatitis B	59	32
Chronic hepatitis C	6	1
Chronic hepatitis B and C	0	1
Alcoholism	1	0
Wilson's disease	0	1
Primary biliary cirrhosis	2	1
Cryptogenic cirrhosis	1	0
Fulminant hepatic failure		
Idiopathic cause	5	0
Acute hepatitis B	1	0
Acute hepatitis E	1	0
Autoimmune hepatitis	1	0
Drug-induced hepatitis	1	0
Acute-on-chronic hepatic failure		
Chronic hepatitis B	44	14
Chronic hepatitis C	1	0
Chronic hepatitis B and C	0	1
Fulminant Wilson's disease	1	1
Polycystic liver disease	0	1
Familial amyloidotic polyneuropathy	0	1
Citrullinemia	0	1
Primary hyperoxaluria	0	1

The graft weight to estimated standard liver weight ratio was significantly lower in the RLDLT group (median, 0.489 versus 0.982, $P < 0.001$, Table 3). The cold ischemic time of liver grafts was much shorter (median, 113 minutes versus 362 minutes, $P < 0.001$), but the time required for graft implantation was significantly longer (median, 273 minutes versus 244 minutes, $P = 0.017$) in the RLDLT group. Twenty-two (18%) patients in the RLDLT group and 9 (16%) patients in the CWLT group did not require blood transfusion. However, the requirement for intraoperative fresh-frozen plasma transfusion was significantly higher in the RLDLT group because of worse clotting profile before transplantation.

Details of postoperative data of both groups of patients are listed in Table 4. The median postoperative ICU stay was 4 days in both groups. The postoperative hospital stay was also comparable (median, 19 days versus 17 days). The hospital mortality rate in the RLDLT group was 1.6%, and that of the CWLT group was 5.4%. Hospital mortality did not occur in the last 105 consecutive patients in the RLDLT group. The overall operative morbidity was also comparable in both groups of patients (43% versus 46%, $P = 0.644$). However, there was a significantly higher incidence of biliary complications in the RLDLT group. While the incidence of

TABLE 3. Operative Data of 124 Patients Who Underwent Right Lobe Live Donor Liver Transplantation (RLDLT) and Those of 56 Patients Who Underwent Cadaveric Whole-Graft Liver Transplantation (CWLT)

Parameter	RLDLT Group	CWLT Group	*P*
Graft weight (g) [median (range)]	600 (365–1120)	1140 (708–1785)	<0.001*
Graft weight/donor body weight (%) [median (range)]	1.04 (0.80–1.52)	1.85 (1.25–2.65)	<0.001*
Graft weight/recipient body weight (%) [median (range)]	0.895 (0.49–1.95)	1.87 (1.11–3.10)	<0.001*
Graft weight/recipient ESLM (%) [median (range)]	49 (29–89)	98 (59–161)	<0.001*
Graft cold ischemic time (min) [median (range)]	113 (72–334)	362 (242–884)	<0.001*
Operating time (min) [median (range)]	703 (470–1195)	485 (290–810)	<0.001*
Implantation time (min) [median (range)]	273 (154–585)	244 (123–475)	0.017*
Intraoperative blood product transfusion (unit) [median (range)]			
Red blood cell	6 (0–34)	4 (0–148)	0.593
Fresh frozen plasma	11 (0–33)	8 (0–49)	0.046*
Platelet concentrate	10 (0–44)	10 (0–79)	0.271
No. of patients without blood transfusion	22 (17.7%)	9 (16.1%)	0.783

*$P < 0.05$.
ESLM indicates estimated standard liver mass.

TABLE 4. Postoperative Data of 124 Patients Who Underwent Right Lobe Live Donor Liver Transplantation (RLDLT) and Those of 56 Patients Who Underwent Cadaveric Whole-Graft Liver Transplantation (CWLT)

Parameter	RLDLT Group	CWLT Group	*P*
Postoperative intensive care unit stay (days) [median (range)]	4 (1–47)	4 (1–125)	0.854
Postoperative hospital stay (days) [median (range)]	19 (7–114)	17 (1–1163)	0.087
Operative morbidity	53 (42.7%)	26 (46.4%)	0.644
Hospital mortality	2 (1.6%)	3 (5.4%)	0.175
Follow-up duration* (mo) [median (range)]	27 (0.8–56)	25 (0.03–55)	0.069
Biliary complication	32 (25.8%)	4 (7.1%)	0.004†
Biliary leakage	5 (4.0%)	2 (3.6%)	1
Biliary stricture	31 (25%)	3 (5.4%)	0.002†
Actuarial graft survival on follow-up	109 (87.9%)	47 (83.9%)	0.468
Actuarial patient survival on follow-up	111 (89.5%)	47 (83.9%)	0.289

*Minimal follow-up duration for patients who were alive was 6 months.
†$P < 0.05$.

biliary leakage was comparable, the incidence of biliary stricture was significantly higher in the RLDLT group on follow-up. With a median follow-up of 27 months (and a minimal follow-up period of >6 months in patients who were alive at the time of preparation of the manuscript), 31 (25%) patients in the RLDLT group developed biliary stricture, which was significantly higher than that of 5% in the CWLT group ($P = 0.002$). Treatment of postoperative biliary stricture in the RLDLT group included endoscopic stenting and balloon dilatation of the stricture (n = 18), percutaneous transhepatic biliary drainage and percutaneous balloon dilatation (n = 7), and surgical reconstruction (n = 6). There was no statistically significant difference in the graft and patient survival after liver transplantation (Figs. 1, 2). At a median follow-up of 27 months, the actuarial graft and patient survival rates were 88% and 90%, respectively, in the RLDLT group. Both the actuarial graft and patient survival rates were 84% in the CWLT group at a median follow-up of 25 months (Table 4). The causes of the 15 graft losses during the follow-up period in the RLDLT group were recurrent hepatocellular carcinoma (n = 6), recurrent hepatitis C infection (n = 2), portal vein thrombosis (n = 1), biliary sepsis (n = 1), systemic fungal infection (n = 1), legionnaires' disease (n = 1), dissecting aortic aneurysm (n = 1), systemic sepsis (n = 1), and myeloblastic anemia (n = 1). The causes of the 9 graft losses in the CWLT group were sepsis and multiorgan failure (n = 6), recurrent hepatitis B infection (n = 1), recurrent hepatocellular carcinoma (n = 1), and central pontine myelinolysis (n = 1). There was no significant clinical factor of the donor or recipient characteristics in the RLDLT group that was found to be associated with graft loss on univariate analysis, partly because of the low incidence of graft loss of 15 (12%) with a median follow-up of 27 months in the RLDLT. Graft and patient survival demonstrated no significant association with clinical factors, including preoperative ICU stay and MELD scores of the recipients, as well as age and gender of the donors.

The live donors for the corresponding 124 RLDLT recipients included 50 men and 74 women with a mean age of 36 years (range, 18–56 years). The body weight of the donors was less than that of the corresponding recipients in 92 cases (74%). The median duration of the donor operation

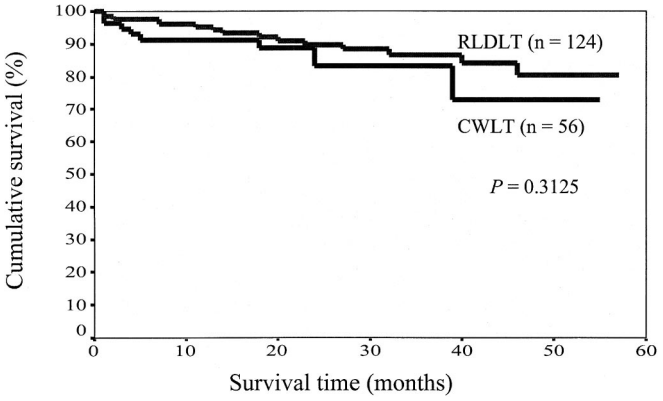

FIGURE 1. Cumulative graft survival of the RLDLT group (n = 124) and the CWLT group (n = 56).

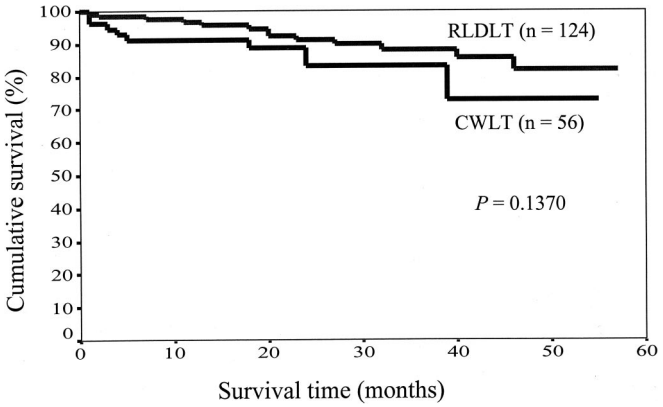

FIGURE 2. Cumulative patient survival of the RLDLT group (n = 124) and the CWLT group (n = 56).

was 7.5 hours and the median operative blood loss was 350 mL (range, 42–1400 mL). No preoperative autologous blood donation was performed in any of the donors. There was no donor mortality and no donor required any blood or blood product transfusion. A total of 22 complications occurred after donor hepatectomy, resulting in an overall operative morbidity rate of 18%. Eighteen of these complications were minor complications, including wound infection (n = 14), occipital pressure sore (n = 2), urinary tract infection (n = 1), and atelectasis (n = 1). Major complications occurred in 4 (3%) donors. Two donors developed significant cholestasis with a total serum bilirubin of higher than 100 μmol/L after donor right hepatectomy. This was considered to be related to a small liver remnant, with the liver remnant to body weight ratio being 0.53% and 0.67%, respectively. The liver remnant was estimated to be 31% of the total liver volume in both the donors. Both of them had spontaneous recovery of liver function without further complications within 2 weeks. One donor developed postoperative biliary stricture and required endoscopic stenting and dilatation for 3 sessions in 3 months postoperatively. The complication was probably caused by division of the right hepatic duct very close to the confluence during donor hepatectomy. He was well subsequently without symptoms with a follow-up of 42 months. Another donor had an intraoperative complication of portal vein thrombosis, which was recognized and rectified during the same operation. The postoperative course of the donor was uneventful. Postoperative imaging studies demonstrated the patency of the portal vein. She was well with normal liver function on subsequent follow-up.

During the study period from January 2000 to February 2004, 135 patients died while on liver transplant waiting list. The figure corresponded to a mortality rate of 43% on the waiting list. This group of patients did not opt for LDLT or no suitable donors were identified. Because of the scarce supply of cadaveric liver grafts in our locality, they died of various complications of chronic liver diseases before a timely liver graft was available.

DISCUSSION

RLDLT has become an accepted procedure in both Western and Eastern societies. It provides a realistic hope of new life for thousands of recipients worldwide who otherwise would have limited or delayed access to a cadaveric organ. Two recent large-scale retrospective studies suggested that, despite selecting recipients with a better preoperative health status, the long-term graft survival outcomes were shown to be inferior to those of CWLT recipients, with a comparable patient survival rate. Abt et al reported a retrospective study on 731 adult-to-adult live donor liver transplantation (AALDLT) recipients and compared their survival outcomes with those of 14,359 patients who received cadaveric liver grafts from January 1998 to December 2001.[8] Despite the favorable donor and recipient characteristics, the rate of allograft failure increased among AALDLT (hazard ratio = 1.66) compared with cadaveric recipients. Older donor age (>44 years), female-to-male donor to recipient relationship, recipient race, and the recipients' medical condition before transplant were factors related to allograft failure.

In another recent retrospective analysis on 764 recipients of AALDLT reported by Thuluvath and Yoo using the United Network for Organ Sharing database, despite their more stable liver disease before liver transplantation, the graft survival was significantly inferior when compared with that of 1470 matched patients who received cadaveric grafts.[9] The 2-year graft survival rate was 64.4% in the AALDLT group compared with that of 73.3% in the cadaveric liver transplantation group ($P < 0.001$), while the patient survival rates were comparable (79.0% versus 80.7%, $P = 0.5$).

In RLDLT, the procurement of the liver grafts was performed under controlled conditions in healthy donors without any hemodynamic instabilities with a short cold ischemic time of the grafts. The procedure was also performed on a selected and more favorable group of recipients, and yet the above 2 studies demonstrated worse graft survival rates compared with cadaveric transplants. However, these 2 retrospective studies on data from multiple transplant centers did not examine the potential influences from the experience of the centers that perform RLDLT. It is anticipated that the operative outcomes should be improved with accumulation of experience of the transplant center. Indeed, such an improvement has been observed in pediatric recipients undergoing

LDLT, in which graft and patient survivals are now equivalent to those of patients receiving cadaveric grafts.[24] In addition, refinement of surgical techniques as the experience of the transplant center accumulates has been demonstrated to associate with an improvement in the operative and survival outcomes in RLDLT recipients.[25] Cross-fertilization of the experience of transplant centers on major hepatic resection for hepatobiliary diseases and LDLT should also not be underestimated.

Graft size mismatch and the resulting small-for-size phenomenon have been incriminated as the causes of inferior operative outcomes in RLDLT. The small-for-size phenomenon has been described as a predisposing factor for the development of graft failure in animal models and human transplantation.[26] However, results of the present study demonstrated that, despite using liver grafts of significantly smaller size, RLDLT could result in favorable operative and survival outcomes in patients with preoperative health status comparable with those of CWLT recipients. Although graft size is an important factor for the success of liver transplantation, the importance of a uniformly good venous drainage of the anterior section of the right lobe liver graft as a crucial factor for the satisfactory postoperative liver function in RLDLT has gained wide acceptance.[27] We adopted a policy of routine inclusion of the middle hepatic vein in the right lobe liver grafts, and we have observed satisfactory operative outcomes of our RLDLT recipients. In patients with poor function reserve, including those with fulminant hepatic failure and acute decompensation of chronic liver failure, this is particularly crucial in providing sufficient functioning liver volume with good venous drainage to meet the high metabolic demand of the recipients to result in favorable survival outcomes.

Other factors that might have contributed to a satisfactory operative outcome of our patients undergoing RLDLT included the short waiting time for liver transplantation and avoidance of surgical complications, especially sepsis resulting from biliary leakage. The duration of waiting for liver transplantation can significantly affect the survival outcome,[28] especially in patients with fulminant hepatic failure and acute-on-chronic liver failure. Significant complications, including intracranial bleeding or sepsis, may occur while the patients are waiting for a suitable liver graft. These may render them unsuitable candidates for transplantation. Other complications such as chest infection and gastrointestinal bleeding may also significantly affect the outcome of transplantation. The median preoperative waiting time for liver transplantation in the RLDLT was 14 days, which was significantly less than that of 237 days in the CWLT group. In those patients on high-urgency list for liver transplantation, the median waiting time for RLDLT was 3 days. Avoidance of surgical complications is also a key factor in improving the survival outcomes of patients after RLDLT. Postoperative complications, especially sepsis, caused by biliary leakage have a deleterious effect on liver regeneration of the small-for-size graft from RLDLT. Biliary complications have been reported to be the frequent causes of graft failure and recipient morbidity and mortality after LDLT.[16,29] In the present series, postoperative bile leakage occurred in 4% of the patients in the RLDLT group, which was not different from that of 3.6% in the CWLT group. Technical refinement of both donor and recipient operations, including detailed evaluation of the biliary anatomy of the liver graft, preservation of the arterial blood supply of the bile duct, and meticulous technique of biliary anastomosis, contributed significantly to the low incidence of bile leakage after RLDLT.[15,16,30]

It has been suggested that right lobe liver grafts from live donors are marginal grafts, and RLDLT should not be used in patients with poor preoperative health status, including those with fulminant hepatic failure, acute decompensation of chronic liver diseases who are ICU-bound and on life support. As a result, most of these patients who are actually in urgent need for transplantation are deprived of a timely liver graft. Short-term mortality without liver transplantation approaches 100% in these critically ill patients with high MELD scores. In the present study, more than 50% of our patients with chronic liver disease had a MELD score of higher than 20 with an estimated 3-month death rate of 76%.[21] In addition, the procedure was performed on 58 patients who were ICU-bound and on the high-urgency list for liver transplantation, among whom 9 had fulminant hepatic failure. There was a significantly smaller number of patients who were ICU-bound in the CWLT group. The observation was not unexpected, since only a small number of these patients could receive a timely cadaveric graft in our locality.[10] Nonetheless, the operative outcomes of the RLDLT group were not inferior to those of the CWLT recipients. While retrospective studies often compared the survival outcomes of RLDLT with those of CWLT, the significance of the impact of RLDLT on mortality on the waiting list has seldom been evaluated. In a study we have previously reported, waiting time mortality was significantly lower in the RLDLT group compared with the CWLT group.[31] A similar beneficial effect of RLDLT has also been reported in a study conducted in the United States.[32] To study the effects of RLDLT on survival from listing to liver transplantation, future studies should investigate the survival outcome measured from the time of listing through transplantation to last follow-up.

Biliary complications, especially biliary stricture on long-term follow-up, remain the Achilles' heel of RLDLT and have previously been discussed.[15,30] The incidence was reported to be higher than 20% on long-term follow-up. The present study again confirmed the incidence of biliary stricture of 25% after a median follow-up of 27 months, which was significantly higher than that after CWLT. This finding represented the only inferior outcome of the RLDLT group. Previous studies have evaluated the possible factors associated with an increased risk of postoperative biliary complications. These included multiple ductal openings[33] and a high preoperative MELD score ($\geq$35) associated with relatively inadequate arterial perfusion.[15] Ischiko et al suggested that using continuous suture combined with an external stent might result in a lower biliary complication rate, and this represented a useful technique for RLDLT.[30] However, other investigators did not identify any significant factor associated

with an increased risk of biliary complications after RLDLT.[34] Nevertheless, complications related to biliary drainage tube, including dislodgement and biliary leakage after removal of the tube, have frequently been reported.[34] It was therefore controversial whether a biliary drainage tube should be inserted after duct-to-duct biliary anastomosis in RLDLT. In our practice, we do not insert biliary drainage tube and did not encounter a high incidence of biliary leakage. Late biliary stricture was the only significant complication that we encountered. Fortunately, most of the biliary strictures encountered in the present study were found amenable to subsequent treatment, including dilatation through endoscopic or percutaneous route, or surgical reconstruction. We have not experienced any significant impact of the complication on graft and patient survival in the present series compared with those who received CWLT.

CONCLUSION

Despite being a more complex operation with smaller graft volume, RLDLT results in favorable operative outcomes comparable with those of CWLT. Right lobe liver grafts should not be considered as marginal grafts. However, there is a significantly higher incidence of biliary stricture associated with RLDLT. Further refinement in biliary reconstruction technique is required before RLDLT becomes a standard operation.

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